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# *Indian Standard*

# SPECIFICATION FOR SHELL AND TUBE TYPE MARINE HEAT EXCHANGERS

## PART 2 GENERAL REQUIREMENTS

UDC 629·12·061 : 66·045·1 : 621·643·2

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Gr 5 *May* 1984

# Indian Standard

# SPECIFICATION FOR SHELL AND TUBE TYPE MARINE HEAT EXCHANGERS

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# *Indian Standard*

# SPECIFICATION FOR SHELL AND TUBE TYPE MARINE HEAT EXCHANGERS

## PART 2 GENERAL REQUIREMENTS

## 0. FOREWORD

**0.1** This Indian Standard was adopted by the Indian Standards Institution on 30 December 1983, after the draft finalized by the Marine Engineering Sectional Committee had been approved by the Marine, Cargo Movement and Packaging Division Council.

**0.2** Shell and tube type heat exchangers are widely used on boardships for duties such as heating, cooling and evaporating. This standard lays down the general requirements and gives guidance for the design and construction of such heat exchangers.

**0.3** The requirements given in this standard are in addition to those given in IS : 4503-1967* which mainly caters to the needs of chemical process industry.

**0.4** The design requirements given in this specification are based on those given in IS : 2825-1969†.

**0.5** The Indian Standards referred to in Table 1 and Table 2 are given in Appendix A.

## 1. SCOPE

**1.1** This specification covers the general requirements for the design, construction and testing of shell and tube type heat exchangers for use on boardships.

## 2. TERMINOLOGY

**2.1** For the purpose of this standard definitions given in IS : 4503-1967* shall apply.

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*Specification for shell and tube type heat exchangers.

†Code for unfired pressure vessels.

## 3. TYPES AND NOMENCLATURE

**3.1 Types** — Shell and tube type heat exchangers for marine use may be broadly classified into three types:

a) Fixed tube plate—non-removable tube bundle,
b) U-tube—removable tube bundle, and
c) Internal floating heat ( pull-through type).

**3.2 Nomenclature** — The nomenclature given in IS : 4503-1967* shall apply far the purpose of this standard.

## 4. MATERIALS

**4.1** All ferrous and non-ferrous materials used in the manufacture of marine heat exchangers shall conform to one of Indian Standards of designated alloys given in Table 1 and Table 2, respectively. If no standard exists for a particular material, the use of this material shall be agreed to between the purchaser, the manufacturer and the inspecting authority.

## 5. GENERAL REQUIREMENTS

**5.1** All heat exchangers shall be designed in accordance with IS : 2825-1969† and shall in addition take into account the requirements given in subsequent clauses in the design of marine heat exchangers.

**5.2** Salt water cooled heat exchangers other than main and auxiliary steam condensers shall be of the straight-through single pass design wherever possible. The water entry may be either axial with the tubes or across the tube plate face as may be dictated by design considerations, but whichever form of entry is used the doors must be capable of easy removal without disturbing connecting water service piping, so that water spaces and tubes plates may be readily cleaned. Alternatively, the doors may be fitted with adequate handholes for ready access to the water space. In multi-pass coolers the water inlet shall be at the bottom of the water space and outlet at the top or both at the bottom itself in case of two passes.

**5.3** Heads shall be so designed that it will not be necessary to disassemble piping to gain access to the inside of the heads and tubes.

**5.4** The tube bundle shall be of the removable type for easy cleaning and maintenance.

**5.5** In the design of cooling water spaces and connections, a smooth flow path shall be provided to minimize erosion-corrosion attack. Sharp corners and projecting edges shall be avoided.

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*Specification for shell and tube type heat exchangers.

†Code for unfired pressure vessels.

## TABLE 1 FERROUS MATERIALS

( *Clauses* 0.5 *and* 4.1 )

| DESIGNATED MATERIAL / COMPONENT | INDIAN STANDARDS ON | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Casting | | | Forging | | | | Tubes and Pipes | | | | | | | Plate | | | | Structural Steel Section | | | Bar |
| | IS : 3038 | IS : 2856 | IS : 3444 | IS : 2004 | IS : 2611 | IS : 1570 | | IS : 3609 | IS : 1570 | | IS : 1914 | IS : 2416 | IS : 1978 | IS : 1979 | IS : 2002 | IS : 2041 | IS : 1570 | | IS : 226 | IS : 961 | IS : 2062 | IS : 1990 |
| | Grades 1, 2, 3, 4, 5, 6 | Grade 1, 2 | Grades 7, 8, 11 13 | Class 2, 3, 4 | 15Cr90 Mo55 | 20Mo55, 10Cr2Mo1 | 04Cr18Ni11, 04Cr18Ni10Ti 20,04Cr18Ni 10Nb40, 04Cr 17Ni12Mo2, 04Cr17Ni12 Mo2Ti20 | 1Cr½Mo Normalized and Tempered 2¼Cr1Mo Normalized | 20Mo55 | 04Cr18Ni11, 04Cr18Ni10Ti 20,04Cr18Ni 10Nb40, 04Cr 17Ni12Mo2, 04Cr17Ni12 Mo2Ti20 | 32kgf/cm²/ 43kgf/cm² Min Tensile Strength | 32 kgf/cm² Min Tensile Strength | Grade St18, St20, St21, St25 | Grade St 30, 32, 37 | Grade 1, 2A, 2B | 20Mo55, 20Mn2 | 15Cr90Mo55, 15 C8 | 04Cr18Ni11, 04Cr18Ni10Ti 20,04Cr18Ni 10Nb40, 04Cr 17Ni12Mo2, 04Cr17Ni12 Mo2Ti20 | Fe410 S | St55HTW | Fe410W | |
| Shell | × | × | × | | | | | | | | | | | | × | × | × | × | | | | |
| Shell Cover | × | × | × | ×* | ×* | ×* | ×* | | | | | | | | × | × | × | × | | | | |
| Channel and Channel Cover | × | × | × | | | | | | | | | | | | × | × | × | × | | | | |
| Tubes | | | | | | | | × | × | × | × | × | × | × | | | | | | | | |
| Tube Sheet | | | | × | × | × | × | | | | | | | | × | × | | × | | | | |
| Nozzle and Branch Pipes | | | | | | | | × | × | | × | × | × | × | | | | | | | | |
| Floating Head | × | × | × | | | | | | | | | | | | × | × | × | × | | | | |
| Flanges | × | × | | × | | × | | | | | | | | | × | × | × | × | | | | |
| Baffle and Support Plates | | | | | | | | | | | | | | | × | × | × | × | | | | |
| Supports | | | | | | | | | | | | | | | | | | | × | × | × | |
| Stay Bars | | | | | | | | | | | | | | | | | | | | | | × |

*Only for small heat exchangers.

## TABLE 2 NON-FERROUS MATERIALS

( *Clauses* 0.5 *and* 4.1 )

| DESIGNATED MATERIAL / COMPONENT | INDIAN STANDARDS ON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Casting | Tubes | | | | Plate, Sheet, Strip | | Bar and Rod | | Section |
| | IS : 318 | IS : 407 | IS : 1545 | | IS : 2501 | IS : 410 | IS : 1972 | IS : 288 | IS : 4171 | IS : 291 |
| | Grade LTB-2, LTB-3 | CuZn30As, CuZn37 | CuNi10Fe1 | CuZn21Al2As (Aluminium Brass) | | CuZn30, CuZn37 CuZn40 | All Grades | | | Grade 1, Grade 2 |
| Shell | × | | | | | × | × | | | |
| Shell Cover | × | | | | | × | × | | | |
| Channel and Channel Cover | × | | | | | × | × | | | |
| Tubes | | × | × | × | × | | | | | |
| Tube Sheet | | | | | | × | × | | | |
| Nozzle and Branch Pipes | | × | × | × | × | | | | | |
| Floating Head | × | | | | | × | × | | | |
| Flanges and Bolting | | | | | | × | × | × | × | |
| Baffle and Support Plates | | | | | | × | × | | | |
| Supports | | | | | | | | | | × |
| Stay Bars, Tie Rods, Spacers | | | | | | | | × | × | |

**5.6** The minimum tube sheet thickness shall be usually not less thon 20 mm.

**5.7** When external fins are applied to tubes, one end of the tubes shall be enlarged to the outside diameter of the fins to enable the removal and insertion of individual tubes.

**5.8** Holes in the tube sheet at the inlet end of the tubes shall be flared to allow for belling the ends of the tubes.

**5.9** In order to diffuse the entering stream and reduce erosion of tube ends, for single-pass coolers the waterbox depth measured normal to the tube sheet shall be not less than one-half the equivalent diameter of the tube sheet area exposed to the flow of the cooling water into the tubes. For cylindrical two-pass coolers, the water box head depth shall be not less than 35 percent of the inside shell diameter.

**5.10** In the design of marine heat exchangers, consideration shall be given to the varying degrees of inclination encountered in service. In marine practice, heat exchangers are to be designed so that they will remain efficient with the ship inclined from the normal up to 15° transversely and when pitching 10° longitudinally and when rolling up to 22·5° from the vertical. The conditions for permanent list and roll or for trim and pitch are not considered additive.

**5.11** All heat exchangers shall be provided with adequate foundation supports. When required by the conditions of service, provision is made in the design of the supports to provide for expansion or contraction of the shell. Heat exchanger supports are usually independent of any attached piping. Supports must be given special consideration when designing for high-impact shock conditions and vibrations.

Tubes should be adequately supported by baffle plates over the length in order to obviate vibrations causing shearing at tube end. Baffles when fitted should be a good fit within the shell, and the holes through which the tubes pass should be chamfered in order to obviate sharp edges.

## 6. CONSTRUCTION

**6.0** All heat exchangers shall have the constructional features in accordance with IS : 2825-1969* and shall in addition take into account the points specified in **6.1** to **6.7**.

**6.1 Lifting Devices** — Channels, bonnets or covers which weigh over 30 kg shall be provided with lifting lugs, rings or tapped holes for eye bolts.

**6.2 End Flange Finish** — All end flanges shall be finish machined where necessary after completion of all welding and postweld heat treatment.

---

*Code for unfired pressure vessels.

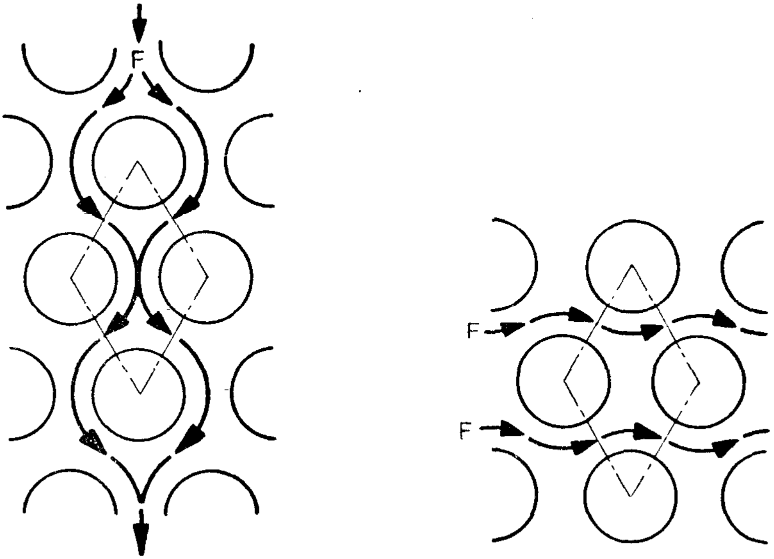
**6.3** Bosses and plugs shall be provided, wherever necessary.

## 6.4 Shell

**6.4.1** The minimum thickness of shells shall be in accordance with IS : 4503-1967*.

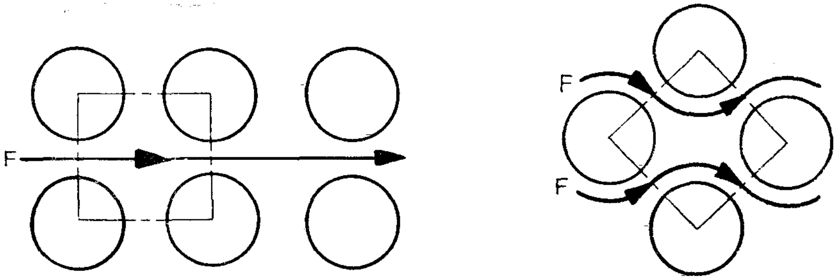
## 6.5 Tubes

**6.5.1** The four most common tube patterns, as viewed from the tube sheet end are shown in Fig. 1.



a) Triangular Tube Pitch

b) Rotated Triangular Tube Pitch



c) Square Tube Pitch

d) Rotated Square Tube Pitch

Fig. 1 Common Tube Patterns

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*Specification for shell and tube type heat exchangers.

**6.5.1.1** The triangular pitch and rotated triangular pitch are the most compact forms and the triangular pattern is the one most commonly used for marine heat exchangers.

**6.5.1.2** Square pitch and rotated square pitch patterns have see-through lanes which facilitate manual or mechanical cleaning of the outside of the tubes.

**6.5.1.3** Tube patterns other than the four illustrated in Fig. 1 may be used to satisfy specific design considerations as to pressure drop or turbulence.

**6.5.2** The tube diameters and thicknesses shall be in accordance with IS : 4503-1967*.

**6.5.3** Tube centre-to-centre distances shall be 1·25 times the tube diameter, or greater and uniform over the tube field.

**6.5.4** Since the shell and tubes operate at different temperatures, means shall be provided to accommodate the difference in their expansion, as high stresses may be developed within the heat exchanger.

### 6.6 Tube Sheets

**6.6.1** *Double Tube Sheets* — Double tube sheets may be used when operating conditions indicate their desirability.

**6.6.1.1** Double tube sheets of the edge welded type shall be provided with vent and drain connections at the high and low points of the enclosed space.

**6.6.1.2** Special attention shall be given to the ability of the tubes to withstand without damage, the mechanical and thermal loads imposed on them by this construction.

**6.6.2** *Expanded Tube Joints*

**6.6.2.1** *Length of expansion* — Tubes shall be expanded into the tube sheet for a length of 50 mm or tube sheet thickness minus 3 mm whichever is smaller. In no case shall the expanded portion extend beyond the shell side face of the tube sheet. When specified, tubes may be expanded for the thickness of the tube sheet.

**6.6.2.2** *Contour of expanded tube* — The expanding procedure shall be such as to provide substantially uniform expansion throughout the expanded portion of the tube, without sharp transition to the unexpanded portion.

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*Specification for shell and tube type heat exchangers.

**6.6.2.3** *Tube projection* — Tubes shall extend beyond the face of each tube sheet by 3+1·5 mm except that tubes shall be flush with the top tube sheet in vertical exchangers.

**6.6.3** *Clad and Faced Tube Sheets* — The nominal cladding thickness at the tube side face of a tube sheet shall not be less than 8 mm when tubes are rolled only, and 3 mm when tubes are welded to the tube sheet. The nominal cladding thickness on the shell side face shall not be less than 10 mm. All surfaces exposed to the fluid, including gasket seating surfaces, shall have at least 3 mm nominal thickness of cladding.

**6.7** The requirements relating to flanges, baffles and support plates, tie-rods, channels and channel-covers, gaskets etc, shall be as per IS : 4503-1967*.

## 7. CORROSION AND CORROSION ALLOWANCE

### 7.1 Corrosion Allowance

**7.1.1** Unless otherwise required, the corrosion allowance for the various parts of the heat exchanger shall be as follows:

a) Carbon steel and cast iron pressure parts — 1·15 mm on all parts except tubes, in the case where severe conditions are not expected;

b) Stainless steel and non-ferrous pressure parts — none or as may be specified by the purchaser.

Floating head backing devices, internal bolting, non-pressure parts, such as tie-rods, spacers, baffles and support plates need not have any allowance for corrosion.

**7.1.2** *Internal Covers* — Internal covers shall have a corrosion allowance on each side.

**7.1.3** *Tube Sheets* — Tube sheets shall have the corrosion allowance on each side with the provision that on the grooved side of a grooved tube sheet, the depth of the pass partition groove may be considered as available for corrosion allowance.

**7.1.4** *External Covers* — Wherever external covers are grooved, the depth of the groove may be considered as available for corrosion allowance.

**7.1.5** *End Flanges* — Corrosion allowance shall be applied only to the inside diameter of flanges.

**7.2 Electrolytic Corrosion** — Although galvanic corrosion can result from using dissimilar metals, the majority of heat exchangers in cooling water service use both copper-alloy and carbon-steel materials. Due consideration shall be given to the selection of materials and to other anticorrosion measures, such as sacrificial anodes when a heat exchanger is required to handle a fluid which would cause galvanic corrosion.

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*Specification for shell and tube type heat exchangers.

## 8. INSPECTION

**8.1** The purchaser shall be offered all reasonable facilities to inspect at any reasonable time the fabrication at any stage and to reject any part which does not comply with this specification ( *see* also IS : 2825-1969* ).

## 9. TESTING

**9.0** The testing procedure outlined under **9.2** and **9.3** covers only the mechanical design and construction of the heat exchanger, and does not include the process performance.

Each completed heat exchanger shall be hydraulically tested at the manufacturer's works to the appropriate pressure.

Pneumatic testing of heat exchangers shall normally be carried out, except in circumstances where even the smallest trace of the testing liquid cannot be tolerated.

**9.1 Test Facilities** — The manufacturer shall supply free of charge the labour and appliances for testing of complete heat exchangers for hydraulic and pneumatical testing as may be carried out on his premises in accordance with this standard. In the absence of facilities at his own works for making the prescribed tests, the manufacturer shall bear the cost of carrying out the tests elsewhere.

**9.1.1** *Gaskets on Test Equipment* — Heat exchangers shall be tested using the service gaskets so that the exchanger may leave the fabricator's shop in the ' as tested ' condition. If this is not possible then special gaskets may be used by agreement provided they are of the same type as the service gaskets.

**9.2 Hydraulic Test**

**9.2.1** Fresh Water or any non-hazardous, non-corrosive liquid may be used by agreement between the purchaser and the fabricator for hydraulic testing.

The test pressure shall be such that at every point in the vessel, it is at least equal to 1·5 times the design pressure.

The test pressure shall be maintained for a period not less than 30 minutes.

**9.2.2** *Precautions* — Before applying pressure the equipment shall be inspected to see that it is tight and that all low pressure lines and other non-pressure parts that should not be subjected to the test pressure, have been disconnected.

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*Code for unfired pressure vessels.

Vents shall be provided at all high points of the vessel in the position in which it is to be tested to purge possible air pockets while the vessel is being filled.

**9.2.3** *Test Procedure*

**9.2.3.1** *Fixed tube sheet type exchangers* — When the shell side and tube side test pressures are not the same, then the test at the lower pressure shall be done first.

When carrying out the shell side pressure test, the channel cover shall be removed so that leakage from the shell side may be detected.

**9.2.3.2** *Floating head type exchangers ( Shell side test pressure less than tube side test pressure )* — When the required shell side test pressure is less than the required tube side test pressure, the hydraulic test shall be carried out in the following manner:

a) The tube bundle, with channel and floating-head cover in place, shall be tested to the appropriate test pressure.

b) After the above test, the tube bundle shall be inserted into the shell and checked for freedom from binding.

c) The shell side with the tube bundle and channel in position shall then be subjected to the appropriate hydraulic test pressure. During this test, the channel cover shall be removed to detect any leakage from the shell side.

**9.2.3.3** *Floating head type exchanger ( Shell side test pressure equal to or greater than tube side test pressure )* — When the required shell side test pressure is equal to or greater than required for tube side pressure, the hydraulic test shall be carried out in the following manner:

a) The shell and tube bundle shall be inspected separately and the tube bundle inserted into the shell and checked for freedom from binding.

b) With the tube bundle, test ring assembly and channel in position, but with the shell cover, floating head cover and channel cover removed for detecting leakage, the shell side shall be subjected to the appropriate test pressure.

c) With the test ring assembly and shell cover removed, but with the floating head cover, channel and channel cover in position, the tube bundle shall be subjected to the appropriate test pressure.

d) With the shell cover in position ( heat exchanger fully assembled ), the shell side shall again be subjected to the appropriate hydraulic test pressure to determine the tightness of the shell cover joint.

**9.3 Pneumatic Testing** — Air testing shall be carried out under close supervision of the testing authority. Adequate protection such as blast walls or pits, and means for remote observation and control should be provided.

**9.3.1** *Test Pressure* — The pneumatic test pressure shall be at least equal to the design pressure multiplied by the ratio of the safe stress value of the material of construction at the test temperature to that at the design temperature, or 1·25 times the design pressure.

**9.3.2** *Procedure* — The pressure shall gradually be increased to not more than 50 percent of the test pressure. Thereafter the pressure shall be increased in steps of approximately ten percent of the test pressure till the required test pressure is reached. Then the pressure shall be reduced to a value equal to 80 percent of the test pressure and held there while the vessel is inspected.

## 10. MARKING

**10.1** The manufacturer shall provide a name plate of a suitable corrosion resistant material, securely attached to the heat exchanger in a position that is accessible and, if the exchanger is to be lagged, where it will not be obscured, stamped with the following information:

a) Manufacturer's name,

b) Manufacturer's serial number and identification,

c) Design pressure: shell...kgf/cm$^2$ ( gauge ) at...°C,
tube...kgf/cm$^2$ ( gauge ) at...°C,

d) Test pressure: shell...kgf/cm$^2$ ( gauge ) at...°C,
tube...kgf/cm$^2$ ( gauge ) at...°C,

e) The letters 'SR' if stress relieved,

f) The letters 'XR' if completely radiographed, and

g) The number of this standard.

**10.2** The shell cover, floating head cover and channel shall be clearly marked on the edge of the flanges with the serial number of the heat exchanger.

**10.3** For exchangers with removable tube bundles, the stationery tube sheet shall be marked on its edge so as to indicate its correct orientation in the shell.

**10.4** Any additional information, as mutually agreed upon between the purchaser and the fabricator, shall be given on a separate name plate.

## 11. PREPARATION FOR DESPATCH

**11.1 Cleaning** — The inside of all shells shall be ground or wire brushed if necessary to remove loose scale prior to insertion of bundles. Dirt, weld rod stubs and other foreign materials shall be removed from all units.

**11.2 Draining** — All liquids used for hydraulic testing or cleaning shall be drained from all units before shipment.

**11.3 Painting** — All external ferrous parts, other than stainless steel shall be painted with temporary corrosion-preventive paint.

**11.4 Protection of Nozzles** — All flanged faces of nozzles shall be protected to prevent damage, for example, by covering with wooden blank flanges. All threaded connections shall be plugged.

**11.5 Protection of Parts** — Separate parts, such as tube bundles and heads, shall be suitably protected to prevent damage during shipment.

## 12. CERTIFICATE OF COMPLIANCE

**12.1 Pressure Test Certificates** — The fabricator shall supply to the purchaser a certificate stating that the exchanger complies in all respects with this Indian Standard and that it has passed the pressure test specified by this standard.

**12.2 Material Test Certificate** — A detailed certificate, including materials of construction, may be supplied, if agreed to between the manufacturer and the purchaser.

## APPENDIX A

( *Clause* 0.5 )

### LIST OF INDIAN STANDARDS

| | |
|---|---|
| IS : 226-1975 | Structural steel ( standard quality ) ( *fifth revision* ) |
| IS : 288-1981 | Arsenical copper rods for boiler stay bolts and rivets ( *second revision* ) |
| IS : 291-1977 | Naval brass rods and sections ( suitable for machining and forging ) ( *second revision* ) |
| IS : 318-1981 | Leaded tin bronze ingots and castings ( *second revision* ) |
| IS : 407-1981 | Brass tubes for general purposes ( *third revision* ) |
| IS : 410-1977 | Cold rolled brass sheet, strip and foil ( *third revision* ) |
| IS : 961-1975 | Structural steel ( high tensile ) ( *second revision* ) |

| | |
|---|---|
| IS : 1545-1982 | Solid-drawn copper alloy tubes ( *second revision* ) |
| IS : 1570-1961 | Schedules for wrought steels for general engineering purposes |
| IS : 1914 ( Parts 1 to 4 )-1977 | Carbon steel boiler tubes and superheater tubes ( *first revision* ) |
| IS : 1972-1977 | Copper plate, sheet and strip for industrial purposes ( *first revision* ) |
| IS : 1978-1971 | Line pipe ( *first revision* ) |
| IS : 1979-1971 | High test line pipe ( *first revision* ) |
| IS : 1990-1973 | Steel rivet and stay bars for boilers ( *first revision* ) |
| IS : 2002-1962 | Steel plates for boilers |
| IS : 2004-1978 | Carbon steel forgings for general engineering purposes ( *second revision* ) |
| IS : 2041-1962 | Steel plates for pressure vessels |
| IS : 2062-1980 | Structural steel ( fusion welding quality ) ( *second revision* ) |
| IS : 2416-1963 | Boiler and superheater tubes for marine and naval purposes |
| IS : 2501-1972 | Copper tubes for general engineering purposes ( *first revision* ) |
| IS : 2611-1964 | Carbon chromium molybdenum steel forgings for high temperature service |
| IS : 2856-1979 | Carbon steel castings for pressure containing parts suitable for high temperature service ( fusion welding quality ) ( *second revision* ) |
| IS : 3038-1974 | Alloy steel castings for pressure containing parts suitable for high temperature service ( *first revision* ) |
| IS : 3444-1978 | Corrosion resistant alloy steel and nickel based castings for general applications ( *first revision* ) |
| IS : 3609-1966 | Chrome molybdenum steel, seamless, boiler and superheater tubes |
| IS : 4171-1983 | Copper rods for general engineering purposes ( *first revision* ) |

( *Continued from page* 2 )

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